Health Consultation

Evaluation of Cadmium, Lead and Zinc Contamination in Spokane River Fish

Spokane, Spokane County, Washington

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Prepared by
The Washington State Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry,
and the Washington State Department of Ecology

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Foreword

The Washington State Department of Health (DOH) has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste. This health consultation was prepared in accordance with methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. The health consultation allows DOH to respond quickly to a request from concerned residents for health information on hazardous substances. It provides advice on specific public health issues. DOH evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health.

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Glossary

Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Carcinogen	Any substance that can cause or contribute to the production of cancer.
Chronic	A long period of time. A chronic exposure is one which lasts for a year or longer.
Contaminant	Any chemical that exists in the environment or living organisms that is not normally found there.
Dose	A dose is the amount of a substance that gets into the body through ingestion, skin absorption or inhalation. It is calculated per kilogram of body weight per day.
Epidemiology	The study of the occurrence and causes of health effects in human populations. An epidemiological study often compares two groups of people who are alike except for one factor, such as exposure to a chemical or the presence of a health effect. The investigators try to determine if any factor (i.e. age, sex, occupation, economic status) is associated with the health effect.
Exposure	Contact with a chemical by swallowing, by breathing, or by direct contact (such as through the skin or eyes). Exposure may be short term (acute) or long term (chronic).
Hazardous substance	Any material that poses a threat to public health and/or the environment. Typical hazardous substances are materials that are toxic, corrosive, ignitable, explosive, or chemically reactive.
Indeterminate public health hazard	Sites for which no conclusions about public health hazard can be made because data are lacking.
Ingestion rate	The amount of an environmental medium which could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Inorganic	Compounds composed of mineral materials, including elemental salts and metals such as iron, aluminum, mercury, and zinc.
Oral Reference Dose (RfD)	An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs are published by EPA and are given in milligrams of chemical per kilogram body weight per day (mg/kg-day).

Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Remedial investigation	A study designed to collect the data necessary to determine the nature and extent of contamination at a site.
Risk	The probability that something will cause injury, linked with the potential severity of that injury. Risk is usually indicated by how many extra cancers may appear in a group of people who are exposed to a particular substance at a given concentration, in a particular pathway, and for a specified period of time. For example, a 1%, or 1 in 100 risk indicates that for 100 people who may be exposed, 1 person may experience cancer as a result of the exposure.
Route of exposure	The way in which a person my contact a chemical substance that includes ingestion, skin contact and breathing.
U.S. Environmental Protection Agency (EPA)	Established in 1970 to bring together parts of various government agencies involved with the control of pollution.

Background and Statement of Issues

The Washington State Department of Health (DOH) was asked to review and evaluate health risks that may result from the consumption of Spokane River fish. To conduct this evaluation, DOH worked jointly with the Washington State Department of Ecology (Ecology), and the Spokane Regional Health District (SRHD). Spokane River fish and crayfish samples were collected in July and October 1999.[1] These samples were subsequently analyzed for zinc, cadmium and lead contamination. This health consultation evaluates potential human health effects associated with the ingestion of these fish.

Site Background

The Spokane River is a recreational area that is frequented by many people during the warm summer months. In the fall of 1998 and February 1999, the U.S. Geologic Survey (USGS) conducted assessments that examined sediment contamination from the outlet of the Spokane River at the north end of Lake Coeur d Alene, in Idaho, to the point where the Spokane River joins Lake Roosevelt, Washington.[2] This sampling survey found elevated levels of zinc, cadmium, and lead in some sediment along the Spokane River. Since 1980, Ecology has periodically monitored metal concentrations in Spokane River fish. As a result of the elevated concentrations of metals found in sediments, in July and October 1999 USGS and Ecology collected fish samples from the Spokane River. These fish were evaluated for cadmium, zinc and lead contamination.

Community Concerns

Fishing on the Spokane River is variable. The actual time spent fishing the river depends upon many factors including: the river location, the person fishing, and the type of fishing. Fishing populations range from day fishermen or recreational anglers to individuals that may rely on fishing the river for food consumption. Individual residents, members of the Washington Citizens Advisory Committee for Spokane Basin Mining Cleanup Work, and tribal communities have expressed concerns to SRHD, Ecology, and DOH regarding contamination of the Spokane River and its beaches.

Environmental Contamination

As part of a biological and ecological assessment of the Spokane River, fish were collected at five different areas along the Spokane River.[1] These sites ranged from just west of state line (near the Idaho-Washington border) near river mile 96, down river to the Seven Mile Bridge area, at about river mile 63 (Figure 1). The quality assurance project plan that was followed and the laboratory results are available from Ecology.[1,3]

Sampling Area

(Between arrows)

0

Figure 1. Area of the Spokane River that was sampled by USGS and Ecology.

Although both fillet and whole fish data were obtained, zinc and cadmium levels were only determined in whole fish. Lead was analyzed in both fillets and whole fish. The fillet data provide analytical results for individual fish, while the whole fish data are composites. For each location, fish contaminant data were determined from a single composite of five whole fish (or three to five crayfish) and from fillets obtained from five individual fish. Four species of fish were analyzed for metals: crayfish, suckers, mountain whitefish, and trout (wild and hatchery). Three species of fish were analyzed for metals, suckers, mountain whitefish, and trout (wild and hatchery). Crayfish were also analyzed. Crayfish samples were obtained from three locations. Rainbow trout were sampled at four locations.

Sampling locations, species sampled, and contaminant levels are shown in Tables 1 through 3 of Appendix A. All results are reported on a wet-weight basis. Zinc levels in whole fish ranged from 28.4 mg/kg in mountain whitefish at Seven Mile Bridge to a maximum of 150 mg/kg in large-scale sucker near Stateline. Cadmium levels in whole fish were lowest near Greene Street bridge (0.19 mg/kg in large-scale sucker) and highest in crayfish near Plantes Ferry Park (0.44 mg/kg). Lead levels were measured in both whole fish and fillets. Whole fish tended to have higher lead levels than the fillets. Whole fish lead levels were greatest in large-scale sucker near Stateline (4.34 mg/kg). Fillet lead levels were highest in rainbow trout near Stateline (0.48 mg/kg). The lowest whole fish lead levels were in mountain whitefish near Seven Mile Bridge (0.56 mg/kg). Levels of lead in fillets were lowest in mountain whitefish near both Greene Street and Seven Mile Bridge, where lead was not detectable at or above the reported values.

Discussion

The preliminary contaminants of concern in Spokane River fish are zinc, cadmium and lead. These contaminants were further evaluated to determine potential human health risks. While knowledge of the levels of these contaminants in fish tissues is necessary to make health-based judgements, it is also necessary to have information on exposure. As the present focus is evaluating potential health risks that may result from the consumption of these fish, information on fish consumption rates for both the general population, and for populations that may be at the most risk, is desired.

Populations of Concern

Recreational anglers are the primary users of the Spokane River above the Long Lake Reservoir.[4] A significant Native American population that fishes the upper river has not been identified. No tribal lands border the river between Long Lake and the Idaho state line. SRHD has tried to identify populations that frequently fish this area. Potential populations of concern were originally identified as including: sport fishermen and the Russian, Laotian, and Hmong communities.[4] Fishing patterns of these groups were further examined and the results of the SRHD fish consumption survey are discussed in the sections below.

Although a Native American population was not identified by SRHD as being a population of concern along the upper river, to address tribal concerns, a health-based analysis for cadmium and zinc contamination in Spokane River fish was conducted using EPA recommended fish consumption values for Native American subsistence populations. This analysis is shown in Appendix C. Native American subsistence populations were also evaluated for health hazards due to lead contamination in Spokane River fish.

Health-based assessments for cadmium and zinc were conducted using health and exposure assessment techniques for non-carcinogens. The evaluation of the lead hazard was conducted using EPA models for both children and adults. As these methods differ significantly, zinc and cadmium health effects associated with consumption of Spokane River fish will be discussed separately from the evaluation of lead health effects.

Cadmium and Zinc

Determination of Fishing Locations and Consumption Rates

Information on fish collection and consumption along the Spokane River is available from a 1998 fish consumption survey that was conducted by the SRHD Assessment/Epidemiology Center.[4] Populations surveyed in this study included: fishing license holders that rely on the Spokane River for Fishing (627 respondents), the Walleye Club (56 respondents), and two ethnic population groups that use the river as a food source (Russian, and Laotian). While six people participated in a focus group of the Laotian community, approximately 30 members from the Russian community participated in a similar focus group. Data obtained from these surveys are shown in Table 1 and discussed below.

Information on fishing license holders was collected through a survey that was sent through the mail. Of the respondents, 39.4% indicated that they fish the river. The most common fishing locations were identified as the Spokane arm of Lake Roosevelt to the Seven Mile Bridge (42.1%), and Long Lake (35.2%). As many respondents did not complete the full survey, information on fish consumption rates for this population are inconclusive. Of the 70 respondents who did complete this portion of the survey, approximately 70% of them reported eating 1-20 fish per year.

A focus group was held with approximately 20 Walleye Club members to collect general information regarding river usage. Surveys were then sent by mail to 180 members of the Walleye Club. Fifty-six completed surveys were received and of the respondents, 40 persons (71.4%) indicated that they fish the river. Like the license holders, the most common fishing locations were identified as the Spokane arm of Lake Roosevelt to the Seven Mile Bridge (82.5%). Fish consumption rates were not provided for this population.

To collect information on the Russian and Laotian communities, SRHD hired members of the Russian and Laotian communities to serve as interpreters, translate surveys, and coordinate survey distribution. The response rate for the surveys was minimal and therefore the information obtained from the surveys was inconclusive.

For the Russian community, fishing information was obtained at a focus group. Participants in this group reported fishing at sites within the Spokane city limits, at locations nearest to Greene Street and Plantes Ferry Park. The focus group indicated that the Russian community eats fish from the river an average of “one time in two weeks or about four pounds in a month.” The “four pounds in a month” quote implies that two pounds of fish (900 grams) are consumed per meal, on average, by the population. This value is extremely high compared to other populations studied. The frequency rate of “one time in two weeks” is, however, similar to a value established by ATSDR in 1989 (less than one fish meal per week) in the document entitled, The Relationship of Human Levels of Lead and Cadmium to the Consumption of Fish Caught in and Around Lake Couer d’Alene.[5]

Discussions with the six members of the Laotian community revealed that they fished primarily downstream from Seven Mile Bridge. These Laotian community members suggested that two to three meals of Spokane River fish are consumed per month, and that with the smaller fish, such as catfish, two fish are consumed per meal. As trout are difficult to catch, the interviewees indicated that few trout are consumed.

Table 1. Fishing Locations and Consumption Rates.

Population	Fishing Locations	Consumption Rates
Fish License Holders	Downstream of Seven Mile Bridge	1-20 fish per year
Walleye Club Members	Downstream of Seven Mile Bridge	NA
Russian Community	Nearest to Greene Street & Plantes Ferry Park	2 meals per month
Laotian Community	Downstream of Seven Mile Bridge	2-3 meals per month

NA= data not available

Determination of the Types of Fish Consumed

The types of fish consumed by the surveyed populations is discussed below. These data are also summarized in Table 2.

The most popular types of fish caught and kept by fish license holders include walleye, perch and rainbow trout. None of the fish license holders reported keeping any sucker. 91.1% of this population eat either skinned fillets or gutted fish.

The most popular type of fish caught and kept by the Walleye club members include walleye and rainbow trout. Like the fish license holders, none of the Walleye Club members reported keeping any sucker. Of the Walleye Club members, 80% eat fillets only and 15% eat whole gutted fish. Many types of fish, as well as crayfish, are caught and consumed by the Russian community. These fish include rainbow trout, crayfish and large-scale sucker. Fish preparation methods in this community include preparing cutlets (ground fish cakes) by grinding fish after removal of the head and spine. These cutlets may therefore include tiny bones. Russian Community members also pickle and dry fish.

Fish consumed by the Laotians include rainbow trout, perch, bass, and walleye. Crayfish are also consumed. Suckers are not consumed by this group and are instead used for bait. Fish preparation methods were not described in the survey.

Table 2. Fishing Locations and Consumption Rates.

Population	Types of Fish Consumed	Common Fish Preparation
Fish License Holders	walleye, perch, trout	skinned fillets or gutted fish
Walleye Club Members	walleye, trout	fillets or gutted fish
Russian Community	trout, crayfish, sucker	cutlets, ground (after removal of head and spine), pickling, drying
Laotian Community	trout, perch, bass, walleye, crayfish	NA

NA= data not available

Calculating an Ingested Dose for Cadmium and Zinc
To determine an ingested dose, the following site specific data are needed: information on contaminant concentration levels in fish, the fish consumption rate (exposure dose) and frequency (exposure frequency).

Contaminant Concentrations for Cadmium and Zinc
The furthest downstream location sampled in 1999, Seven Mile Bridge, is upstream of the areas most frequently fished by anglers, with the exception of the respondents from the Russian community who fish the river within the Spokane city limits. The Plantes Ferry Park and Greene Street sampling sites are nearby to the locations fished by this community. Contaminant levels of cadmium and zinc in whole fish at all locations are seen in Tables 1-2 of Appendix A. The cadmium and zinc levels that were used for risk estimates are shown below in Table 3. The Plantes Ferry Park area was used for the human health evaluation because this area experiences higher fishing pressure and harvest than the samples collected near the state line area. To ensure the protection of human health, maximum cadmium and zinc levels found in crayfish and large-scale sucker at Plantes Ferry Park were used to calculate ingested doses.

Table 3. Levels of Cadmium and Zinc used for exposure estimates.

Metal	Fish Type	Location Sampled	Maximum Contaminant Level
Cadmium	crayfish	Plantes Ferry Park	0.44 mg/kg
Zinc	large-scale sucker	Plantes Ferry Park	106 mg/kg

Fish Consumption Rate and Frequency

Specific consumption data on a per meal basis are very limited for the Spokane River. As a result, consumption data obtained from two Lake Roosevelt surveys, including a Creel Survey were used.[6,7] The per meal consumption rate in this population was 2.6 fillets and the average trout fillet size was 123 grams.

Although fish license holders on the Spokane River only estimated eating 1-20 fish per year, the Russians and Laotian communities consumed fish meals approximately two to three times per month.[4] To conservatively estimate fish meal consumption frequencies, it was assumed that five fish meals per month, or 60 fish meals, were eaten per year.

Health Evaluation for Cadmium and Zinc Exposure

Using these conservative values, including the specific contaminant levels and the meal frequency rates described above, human exposure doses for cadmium and zinc were estimated. The equation used for these estimates is shown in Appendix B. Based on the assumptions above, the ingested doses for cadmium and zinc are 0.0003 mg/kg-day and 0.08 mg/kg-day, respectively.

To evaluate potential human health risks, ingested doses for cadmium and zinc were compared to federal health-based guidelines. EPA has established Reference Dose values

(RfDs) to protect against adverse non-cancer health endpoints. In general, the RfD is an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily exposure to the human population, including sensitive subgroups, that are likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs include safety factors which protect against uncertainty in the data. Similarly, ATSDR has established Minimal Risk Levels (MRLs). An MRL is defined as an estimate of daily human exposure to a chemical that is likely to be without an appreciable risk of deleterious (non-carcinogenic) effects over a specified duration of exposure. Both RfDs and MRLs have undergone extensive internal and external peer review by panels of scientific experts.

Estimated doses from Spokane River fish ingestion are compared to health-based guidelines in Table 4. As shown, adult exposure to cadmium and zinc in Spokane River fish does not exceed health-based guidelines and is not expected to result in adverse health effects. Similarly, as shown in Appendix C, the exposure of Native American subsistence fishers to cadmium and zinc is also not expected to result in any adverse health effects.

Table 4. Spokane River Contaminants: Estimated Exposures Compared to Health-Based Guidelines.

Contaminant	Health-Based Guidelines		Estimated Exposures	
	EPA-RfD mg/kg-day	ATSDR-MRL mg/kg-day	Adult Dose mg/kg-day	Native American Dose mg/kg-day
Cadmium	0.001	0.001	0.0003	0.0005
Zinc	0.3	0.3	0.08	0.13

Cadmium, Zinc and Children's Exposure

The data on fish consumption levels for children are very limited. For the Spokane River, there are no available data on the amount of fish children consume per meal or the number of fish meals. If one assumes that a child, between the ages of 6 and 18, consumes both the same amount of fish per meal and same number of fish meals as an adult, then the exposure dose for the child would still be below the health screening RfD and MRL values for cadmium and zinc. Appendices B and C shows the formula that was used for this calculation. Since this is a very conservative assumption, no apparent public health hazard due to cadmium or zinc contamination exists for children (ages 6-18) who consume fish from the Spokane River. For very young children, below the age of 6, there is not enough information available to estimate exposure doses.

If we assume that Native American children (ages 6-18) are eating the same quantities of fish as their parents (using consumption values for subsistence fishers), again a very conservative assumption, the health-based screening values for cadmium and zinc are not exceeded.

Limitations and uncertainties of the cadmium and zinc analysis

Estimations of fish consumption levels and frequencies for the populations fishing the Spokane River have been based on very limited information. When collecting information from ethnic communities, both language and cultural barriers can effect the quality and quantity of data obtained. Additionally, due to the mistrust of public officials, it is possible that all fishers under- reported their catch and subsequent consumption. For these reasons, approximations on fish consumption frequency and rate were based upon conservative assumptions that would lead to an overestimation of risks. Similarly, the contaminant level for all fish types consumed was assumed to be equal to the level found in the most contaminated fish, the crayfish for cadmium contaminant levels, and the large-scale sucker for zinc contaminant levels. It was also assumed that the levels of cadmium and zinc found in all fish was equal to the levels found in the most contaminated fish at the most contaminated location that was identified as being fished by the surveyed communities. These assumptions are highly conservative and would most likely result in an overestimation of true exposures.

For the purposes of ecological studies, contaminant levels for cadmium and zinc in Spokane River fish were based upon levels detected in the sampled whole fish. Contaminant data from whole fish are applicable to environmental concerns but not necessarily to public health concerns. For consumption purposes it is strongly recommended that the edible portion of the fish is analyzed. This is also recommended by the EPA.[8] An example of why whole fish data are insufficient for addressing public health issues can be provided by the lead data collected in this study. For lead, data are available for levels in whole fish as well as in fillets. The levels detected in whole fish are consistently higher than levels detected in fillets. This can be seen in Table 1 of Appendix A. The levels in whole fish range from being eight fold greater than the levels in fillet, as found in trout near Greene Street, to up to 145 fold greater in whole fish, as seen in large-scale sucker near Stateline. As most anglers consume fillets and gutted fish, whole fish data do not represent what is generally consumed. Thus the use of contaminant levels of metals found in whole fish, rather than fillets, would result in an overestimation of the actual exposure dose.

Lead

Health effects due to lead exposure were assessed using EPA validated models for children and adults. Since these models are different, children and adults will be considered separately.

Lead Hazard Assessment for Children

The potential lead hazard for children was assessed using EPA=s Integrated Exposure Uptake and Biokinetic (IEUBK) Model for Lead. This model considers total environmental lead exposure. In considering total lead exposure, lead hazard assessment is more conservative than the risk assessment methodology employed for zinc and cadmium, which only considered exposure via fish consumption. Inputs to the IEUBK model include lead exposure through soil, house dust, air, diet, and water. The model predicts distributions of blood lead levels for children 84 months of age or younger. (For a discussion of the meaning of lead blood levels, see the health effects section of this document).

In contrast to other risk assessment methodologies, the IEUBK uses central tendency values (e.g., average or median) for exposure parameter inputs. The model is health protective in that only a small fraction (5%) of modeled blood lead levels can exceed a target value of 10 micrograms per deciliter (mg/dl). For children, a 10 ug/dl blood lead level is considered to be a level of concern by both CDC and EPA.[9,10]

Model Input Values

For the IEUBK model, EPA default values were used except for soil and house dust lead concentrations, and factors related to fish consumption. To assess the lead hazard associated with fish consumption, the model requires information on the percentage of total meat consumption consisting of locally caught fish and the average lead concentration in fish tissue.

Soil and House Dust Lead Concentrations

The soil lead concentration used was derived from children's activity patterns, specifically the duration of time children spent at home and at Spokane River beaches. Certain upper Spokane River beaches have demonstrated lead contamination.[11]

The formula for the soil lead calculation is as follows:

Weighted soil lead concentration **=** (beach lead concentration) **x** (fraction of time children spend at the beach) **+** (home soil lead concentration) **x** (fraction of time children spend at home)

The contribution of beach lead results in an effective soil lead concentration of 230 ppm, slightly greater than the model default value of 200 ppm.[11]

House dust lead concentrations are usually computed as being 70% of soil lead concentrations.[12] It is unlikely that beach sand will contribute significantly to the house dust, as transport of beach sand to the interiors of homes some distance away is expected to be minimal. Nonetheless, the activity pattern based soil lead concentration of 230 ppm was used to calculate a conservative measure of house dust lead concentration. Further detail describing how this value was determined is available from EPA and is the Draft Final Screening Level Human Health Risk Assessment.[11] The house dust concentration used for the model was 161 ppm (230 ppm in soil x 0.70).[12]

Meat Consumption Consisting of Locally Caught Fish

Determining the percent of meat consumption consisting of locally caught fish requires knowledge of daily fish and meat consumption rates. The percentage was then calculated by dividing the daily fish consumption rate by the daily meat consumption rate. Daily meat consumption rates were specified in IEUBK technical guidance.[12]

Data on fish consumption by children are limited. No applicable studies for fish consumption by children of recreational anglers were identified. Three Washington State fish consumption studies provide some information on fish consumption rates for Native American children.[13,14,15] The CRITFC study was the only study which examined freshwater fish consumption by children, and on that basis was judged to be the most relevant study to use for assessing the Spokane River lead hazard for children. The CRITFC study presented Native American fish consumption rates for children between 0 to 72 months of age.[13] Native Americans may practice subsistence fishing, relying on locally caught fish for a substantial portion of their protein intake. It is likely that use of Native American consumption rates will result in an overestimate of the lead hazard to the general population.

Having identified the CRITFC study as the appropriate data source, the next step was to select an appropriate fish consumption rate. The distribution of children's fish consumption rates from the CRITFC study is asymmetrical or right skewed, having a number of individuals with high fish consumption rates. For skewed distributions, the arithmetic mean is an inappropriate measure of an average or central tendency" consumption rate, as its calculation is highly influenced by individuals with large fish consumption rates. A better measure of a central tendency consumption rate for a skewed distribution is the median or 50th percentile. The median consumption rate is the rate such that half of the consumption rates fall below it and half of the consumption rates are above it.

The CRITFC children's fish consumption data has no actual data at the 50th percentile (i.e. median) of the data set. There is actual fish consumption data at the 39th and 65th percentiles of the data set. It would be possible to estimate the median consumption rate by extrapolating between the 39th and 65th percentile consumption rates. However, it was felt that some uncertainty would be introduced by this process. Consequently, the fish consumption rate associated with the 65th percentile of the data set, 16.2 grams per day, was used. Use of the 65th percentile is a conservative, health protective measure of median fish consumption. Since an average fillet weighs about 123 grams, the consumption rate for a child is equivalent to approximately four fillets per month.[6,7]

The percentage of meat consisting of locally caught fish is calculated by dividing the amount of fish consumed per day (16.2 grams) by the amount of meat consumed per day (98.05) grams to yield a value of 16%. A complete presentation of the information supporting this section is included in Appendix D.

Fish Tissue Lead Concentrations

Determining the fish tissue lead concentration to use in the health-based assessment required evaluation of the appropriate species to use, whether to use fillet or whole fish lead concentration data, and how to take sampling locations into account.

The CRITFC study identified species specific consumption rates for fish sampled by Ecology.[13] These species and the percent of children consuming them are as follows: trout 46.5%; whitefish 10.9%; and large-scale sucker 2.0%. Since trout are preferred relative to the other species examined, trout were used to characterize fish tissue lead concentrations. Use of trout data relative to the other species is health protective, as trout fillets had higher lead concentrations than either sucker or mountain whitefish fillets.[1]

The CRITFC study also provided information on the parts of fish consumed by children.[13] Only 3.7% of children consume the fish head. This value was used to indicate the percentage of whole fish consumed by children. Given children's preference for fillets over whole fish,[13] fillet concentrations were selected as the basis for lead health hazard assessment.

To reflect the fact that anglers may prefer individual fishing locations, it was decided to use lead data from the sampling location with the highest average lead concentrations. Trout fillet lead concentration values obtained from the Stateline area were chosen for this analysis. The average lead concentration for these fillets was 0.22 mg/kg. Complete data on lead concentrations in Spokane River fish and crayfish samples are presented in Appendix A, Table 3.

Time Period for Model Evaluation

The usual age range for which the model is evaluated is 0 to 84 months. However, the fish consumption data from the CRITFC study were for children less than 72 months of age. Therefore, the period of model evaluation was set at 0 to 72 months to match the age range over which fish consumption data were available. Use of a lower age range for model evaluation generally results in prediction of higher blood lead concentrations and is health protective.

Health Evaluation of Lead Exposure in Children

Using the model input parameters summarized in Table 2 of Appendix D, the predicted percentage of children having blood lead levels greater than 10 ug/dl was 3.24 %**.** This means that the consumption of fillets, by children, from the Spokane River should be considered safe. No public health hazard exists for children consuming fish fillets from the Spokane River.

Consumption of larger quantities of fish fillets than those assumed in the health-based assessment may have some health effects. Consequently, the IEUBK model was used to develop general guidelines for the permissible number of monthly meals of different species consumed by children. The results of this evaluation are shown in Table 5.

Table 5. Maximum Fillet Meals for Children

Species	8 ounce meals per month
Rainbow Trout	4
Large-scale Sucker	7
Mountain Whitefish	13

Long-term consumption of fillet meals in excess of the rates shown in Table 5 may cause an exceedance of EPA's health protection guideline. This guideline suggests that no greater than 5 percent of all children should have blood lead levels in excess of 10 ug/dl.

The IEUBK model was also used to develop general guidelines for the permissible number of monthly meals of whole fish that could be consumed. This evaluation showed that children (ages 0 through 5) should not be consuming any whole fish meals or any meals made with whole fish.

Limitations and Uncertainties of the Lead Hazard Analysis for Children

The potential hazard predicted by this analysis is dependent on the assumptions used, and changes in these assumptions will affect the calculated hazard. The hazard is likely to be overestimated along segments of the Spokane River where fish tissue lead concentrations are lower than those found at the Stateline sampling station. The hazard may also be overestimated by use of Rainbow Trout fillet concentrations relative to other species.

For those children who consume whole fish, the hazard may be underestimated by the use of fillet lead concentrations. If whole fish lead concentrations are used to assess hazard, then trout lead concentrations would underestimate the hazard relative to using large-scale sucker lead data, which showed higher lead concentrations. Not including crayfish consumption may also underestimate hazard. If lead levels found in whole fish samples were to be used in the IEUBK model, then the health-based criteria that not more than 5% of a population of children exceed the recommended blood lead limit of 10 ug/dl, would be exceeded and a public health hazard might exist.

The impact of a number of assumptions could over or under estimate hazard. The meat consumption rates used to calculate the percentage of locally caught fish associated with meat consumption are likely drawn from the general population and may be greater than or less than meat consumption rates for Native American children. Also uncertain are the relative magnitudes of consumption rates for Native Americans fishing the Spokane River relative to the CRITFC study tribes.

The dietary practices of Russian and Laotian immigrants are not well characterized. Childhood ingestion of whole fish relative to fillets could greatly increase the hazard for these or other minority groups relative to the hazard calculated in this analysis. In particular, Russian anglers are known to grind up whole large-scale sucker for consumption as fish cakes,[4] a practice which could lead to potentially unacceptable hazard.

Lead Hazard Assessment for Adults

Adult lead hazard is evaluated using modeled blood lead levels. The model used is completely separate from the IEUBK model, but is also an EPA validated model.[16] The adult model considers lead exposure through the ingestion of soil and food. The dose of lead received through these pathways is then converted to a blood lead level by using the ratio of blood lead to lead dose. This ratio is called the “biokinetic slope factor” or BKSF. The starting blood lead level, the blood level in the absence of lead exposure via food and soil ingestion pathways, is also part of this calculation. The formula used for the adult lead model is:

Adult blood lead level = (Starting blood lead level) + (BKSF) x (Lead dose)

A more thorough description of the adult lead model and input parameters may be found in Appendix E.

Lead health effects of concern are increased blood pressure (i.e., hypertension) for all adults and protection of the developing fetus for pregnant women. Hypertension in adults has been associated with blood lead levels as low as 7-10 ug/dl.[9, 10] In order to protect the developing fetus, EPA has suggested that central tendency maternal blood lead levels need to be maintained at or below 4.2 ug/dl.[17] However, based on recent data collected on blood levels for women in western Washington, this health consult will use a more protective value of 2.80 µg/dl.[18] Maintenance of the central tendency maternal blood level at or below 2.8 ug/dl should insure a low probability of fetal exposure to blood levels of greater than 10 ug/dl. 10 ug/dl is the same health protective value used for assessment of lead hazard for children in the IEUBK model.

Model Input Values

The values for several of the adult model values are well established defaults that have been established by EPA.[19] These default values are shown in Table 1 of Appendix E. Values for the fish consumption rate and lead concentration are dependent upon the exposure scenario being evaluated and are discussed below.

Adult Fish Consumption Rates

Adult fish ingestion rates vary depending on the population group under consideration. Recreational anglers, Laotians and Russians have been identified as population groups that fish the Spokane River.[4] Native Americans may also fish the Spokane River.[20] Lead hazards were evaluated for each of these groups. Population specific consumption rates are shown below in Table 6. Discussion of how these consumption values were determined is addressed in Appendix F.

Table 6. Consumption Rates Used to Analyze Adult Blood Lead Hazards

Population	Fish Consumption (grams per day)
Native Americans[13]	39.2
Recreational Anglers[4]	7.5
Recreational Anglers[6]	42
Russian Anglers[4]	59.7

Fish Tissue Lead Concentrations

For evaluation of lead hazard, the maximum species specific lead concentration was used as shown in Table 7 below.

Table 7. Lead Concentrations Used to Analyze Adult Lead Hazard

Species	Whole or Fillet	Location	Concentration (mg/kg)
Rainbow Trout (hatchery)	Whole	7 Mile Bridge	1.59

Rainbow Trout (wild)	Fillet	Stateline	0.22
Largescale Sucker	Whole	Stateline	4.34
Largescale Sucker	Fillet	Stateline	0.129
Mountain Whitefish	Whole	Greene St.	0.65
Mountain Whitefish	Fillet	7 Mile Bridge	0.0356
Crayfish	Whole	Plantes Ferry	1.34

Health Evaluation of Lead Exposure in Adults

Table 8, shown below, lists predicted blood lead levels associated with different combinations of fish consumer populations, species, and sample types (i.e., fillets or whole organisms). For the adult lead health assessment, two health endpoints are of concern, fetal protection for pregnant women and hypertension for all adults. The cutoff point for the first endpoint is 2.8 ug lead/dl blood, while the cutoff for the second endpoint is 10 ug lead/dl blood. Blood lead levels exceeding the fetal protection endpoint are italicized while levels exceeding the hypertension endpoint are **bolded**. All population groups consuming **whole** fish may be at risk of exceeding the fetal protection endpoint. The Russian population is the only group that may be at risk for lead induced hypertension due the consumption of whole large-scale sucker. Uncertainties in fish consumption rates could affect this conclusion. For example, using SRHD recreational consumption rates, blood lead levels do not exceed either fetal protection or hypertension endpoints. Based on the endpoints discussed above, a public health hazard exists for adults who consume **whole fish** from the Spokane River. No public health hazard exists for adults who consume **fillets** from the Spokane River.

Table 8. Predicted Adult Blood Lead Levels Associated with Different Populations and Species Consumption

Species	Preparation	Predicted Blood Lead Levels (ug/dl)			
		Recreational (Lake Roosevelt)	Recreational (SRHD)	Russian	Native American
Trout	Fillet	2.62	2.32	2.77	2.60
Trout	Whole	4.92	2.73	6.00	4.75
Sucker	Fillet	2.47	2.29	2.56	2.45
Sucker	Whole	9.54	3.55	12.49	9.06
Crayfish	Whole	4.50	2.65	5.41	4.35
Whitefish	Fillet	2.31	2.26	2.34	2.31
Whitefish	Whole	3.34	2.45	3.79	3.27

Underlined values exceed the fetal protection cutoff of 2.8 ug/dl

Bolded values exceed the hypertension cutoff of 10 ug/dl

ug/dl = micrograms per deciliter SRHD = Spokane Regional Health District

The adult lead model was used to develop general guidelines for the permissible number of monthly meals of whole and fillet fish that could be consumed by adults. The results of this evaluation are shown below in Table 9 for whole fish and in Table 10 for fillets. As Table 10 shows, the meal limits for fillets are fairly high, thus no restrictions are proposed.

Values for the suggested limits of crayfish consumption, as shown in Table 9, are very conservative. The only available contaminant data for crayfish was from the whole crayfish and not the edible portion. Although no comparison data are available, it is anticipated that the levels of lead in the whole crayfish will be much higher than the levels found in the edible portion of the crayfish. Thus health assessments based on whole crayfish data may overestimate the health risk to persons eating only the edible portion of the crayfish. Since no data are available, the health risk due to the consumption of the edible portion of the crayfish is indeterminate at this time.

Table 9. Maximum Whole Fish Meals for Pregnant Women & Adults

Species	8 ounce meals per month	
	Pregnant Women	All Adults
Rainbow Trout	1	16
Largescale Sucker	0	6
Mountain Whitefish	1	40
Crayfish	3	19

Table 10. Maximum Fillet Meals for Pregnant Women & Adults

Species	8 ounce meals per month	
	Pregnant Women	All Adults
Rainbow Trout	8	118
Largescale Sucker	14	202
Mountain Whitefish	52	730

Limitations and Uncertainties of the Lead Hazard Analysis for Adults

The potential hazard predicted by this analysis are dependent on the assumptions used, and changes in these assumptions will affect the calculated hazards. A number of assumptions may result in hazard overestimation. Hazard along some segments of the Spokane River is likely to be overestimated by the use of the highest average fish tissue and crayfish lead concentrations. Use of whole crayfish concentrations is also likely to overestimate the hazard associated with crayfish consumption. Crayfish muscle tissue may have lower lead concentrations than whole crayfish, analogous to the results seen with fish. Use of the 72^{nd} percentile of DOH fish consumption data may also overestimate central tendency recreational fish consumption rates. Additionally, for soil ingestion, the use of 100 mg/day as a soil ingestion rate is a high end estimate of this value.

There has been some suggestion that the CRITFC study may underestimate Native American fish consumption rates.[13] The direct interview techniques used in the CRITFC study may not elicit sufficient or accurate responses from individuals practicing a traditional lifestyle which includes subsistence fishing. It has been suggested that the individuals not accounted for in the CRITFC study would have very high consumption rates.[21] Additionally, there is considerable uncertainty in consumption rate values used for recreational anglers and the Russian population.

Chemical Specific Toxicity Evaluation

Cadmium

Cadmium is a naturally occurring element in the Earth's crust. It is most often present as a mineral combined with other elements such as oxygen, chlorine or sulfur.[22] For the general population, food and cigarette smoke are the biggest sources of cadmium exposure. Compared to non-smokers, smokers may have double the cadmium intake.[21] Inhalation and ingestion are the main routes of exposure to cadmium and the route of exposure can greatly effect the severity of toxic effects.

Cadmium is classified as a B1 probable human carcinogen by EPA.[23] This classification is based on exposure through inhalation. Whether or not cadmium can cause cancer through oral ingestion is currently disputed, but at this time EPA does not consider cadmium to be carcinogenic when exposure occurs through ingestion.[21,22]

Eating foods with very high levels of cadmium can severely irritate the stomach, cause vomiting and diarrhea, and sometimes death.[21] Long-term exposure to low levels of calcium can lead to a build up of cadmium in the kidney and may cause kidney damage. The health-based screening values, the oral RfD and the MRL, for cadmium are based upon adverse effects seen in the kidneys of humans that were chronically exposed to high levels of cadmium in the diet.

Women with low levels of calcium or iron, due to pregnancy or dietary deficiency may absorb more cadmium when exposed to cadmium in food or water.[21] Animal studies support this finding and have shown that more cadmium is absorbed from the diet if the diet is low in calcium, iron, or protein. Children who do not get enough iron, calcium or protein may also absorb more cadmium. Animal studies also indicate that the young are more susceptible than adults to bone loss or decreased bone strength due to exposure to cadmium.[21] The most sensitive indicator of developmental toxicity of cadmium in animals appears to be neurobehavioral development.[21] Adverse effects in these studies were seen at doses that are 40 fold greater than the health-based screening values, and over 130 fold greater than the estimated exposure dose for adults consuming fish from the Spokane River.

Zinc

Like cadmium, zinc is an element that occurs naturally in the Earth's crust. Zinc is an essential element that is required for normal growth, bone formation, brain development, behavioral response, reproduction, fetal development, sensory function, immune function, membrane stability, and wound healing in humans.[24] Many enzymes in the body require a certain low level of zinc in order to function maximally. The National Academy of Sciences estimates a Recommended Daily Allowance (RDA) for zinc of 15 mg/day for adult men, which is equivalent to 0.21 mg/kg-day. For adult women, the RDA is 12 mg/day. During pregnancy and lactation in women, and for infants, higher levels of zinc are recommended.[25] In a review of the data gathered on zinc toxicity, ATSDR was unable to locate information suggesting that specific subpopulations, besides persons who are at greater risk due to unusually high zinc exposures, are unusually susceptible to zinc toxicity.[23]

Although necessary, too much zinc can be detrimental to ones health. Inhalation of zinc can cause metal fume fever.[23] Short-term ingestion of zinc, tenfold higher than the RDA, can cause stomach cramps, nausea, and vomiting.[23] Long-term ingestion of high levels of zinc may cause anemia, damage to the pancreas, and decreases in high density lipoprotein (HDL) cholesterol.[23] The effects of high level zinc on reproductive endpoints is unknown.[23] The oral health-based screening values for zinc, the RfD and the MRL, are based upon the effects of zinc on the blood and the ability high levels of zinc to disturb the balance of copper and iron in the human body.[20, 26] The health-based screening value of 0.3 mg/kg-day is expected to be without adverse effects when consumed on a daily basis for an extended period of time. At this level, no nutritional deficiency is seen and undesirable effects are not expected to occur in a healthy, non-pregnant adult. As mentioned above, pregnant and lactating women and infants may require more zinc.

Presently, there is no reliable human or animal carcinogenicity data to suggest that zinc may be a carcinogen. Zinc is considered by EPA to be not classifiable as to its human carcinogenicity.[25]

Lead
Lead is a naturally occurring bluish-gray metal found in the Earth's crust.[9] Lead is presently found throughout our environment due to many human activities including mining, manufacturing and the burning of fossil fuels. Due to health concerns, the amount of lead in gasolines, paints, pipes, and ceramics has been dramatically reduced in the last 15 years, but since lead is so stable, levels in the environment remain high. Today, the main uses of lead are in the production of batteries, ammunition, and metal products.[9]

EPA has classified lead as a probable human carcinogen (B2 classification) based on animal studies that have shown increases in kidney tumors with dietary and subcutaneous exposure to soluble lead salts.[10] There is no proof that lead causes cancer in humans. Lead is a major public health concern predominantly due to its effects on children's nervous systems. Lead can also have profound effects on blood formation, the immune system, as well as affecting organs such as the kidney, liver and heart.[10]

Health effects of lead are most commonly expressed in terms of internal exposure, or blood lead levels. Blood lead levels reflect the absorbed dose of lead.[10] There does not appear to be a clear threshold for the health effects of lead and numerous studies have tried to correlate environmental lead levels with blood lead levels.[9.10] These comparisons are difficult as the route of exposure and many other environmental factors, including bioavailability, will affect the absorption of lead into the body. For a given site and route of exposure, slope factors can be used in coordination with environmental data to estimate or predict blood lead levels.[10]

Human exposure to lead occurs predominantly through inhalation of dust or chemicals that contain lead, or through ingestion of lead that may be present in food and beverages.[9] Lead is not easily absorbed through the skin. Once lead enters the body, it travels from the bloodstream to many organs including the liver, kidney, brain, lungs, and heart. After several weeks, most of the lead in the body will move to the bones and teeth where it may remain for decades.[9] In adults, high lead levels may cause brain, kidney, and heart damage. Effects on the heart include increases in blood pressure (also known as hypertension). Long-term exposure can decrease the performance of adults in neurological tests. Weakness in the fingers, wrists and ankles may also occur. Lead may cause also anemia (low numbers of blood cells) and in men high levels of lead may decrease sperm production.

In children, the nervous system effects of lead are of greatest concern.[9,10] Low doses of lead may affect mental and physical growth of children and fetuses. Exposure in the womb may result in lower birth weight. Fetal exposure or exposure during early childhood may slow mental development and lower intelligence.[9] These effects can persist past childhood. CDC and EPA consider children to have an elevated level of lead in the blood f the lead level is above 10 ug/dL.[9,10] Medical treatment may be necessary if blood lead levels are above 45 ug/dL. High levels of lead in the blood (above 80 ug/dL) can cause encephalopathy, whereas lower blood lead levels (40 ug/dL) may cause decreases in IQ and alter behavioral profiles. Changes in motor nerve conduction have been seen at blood lead levels as low as 20 ug/dL. The National Research Council, EPA, and ATSDR generally accept a blood lead level of 10 ug/dl to be a level of concern. Some studies have suggested lead may not have adverse effects at this level. The effects of lead at blood lead levels less than 15 ug/dl have proven difficult to separate from other environmental influences (e.g., socioeconomic status). However, the weight of evidence resulting from continued research suggests lead does exert adverse nervous system effects at a 10 ug/dl blood lead level.

Chemical Exposure and Children

Children can be uniquely vulnerable to the hazardous effects of many environmental toxicants. When compared to adults, pound for pound of body weight, children drink more water, eat more food, and breathe more air. Children have a tendency to play closer to the ground and often put their fingers in their mouths. These factors lead to an increased exposure to toxicants in dust and soil. Additionally, before birth, the fetus is highly sensitive to many chemicals that may cause organ malformations and even premature death. For these reasons, it is very important to consider the specific impacts that contaminants may have on children, as well as other sensitive populations.

The health effects of cadmium, zinc, and lead on children who consume fish from the Spokane River has been discussed in the above sections under the health assessment for each particular metal. In summary, no apparent public health hazard due to cadmium or zinc exists for children (ages 6-18) who consume fish from the Spokane River. For very young children, below the age of 6, there is not enough information available to estimate exposure doses. Similarly, no apparent no apparent public health hazard due to cadmium or zinc exists for Native American children (ages 6-18) who consume fish from the Spokane River.

Using the exposure assumptions associated with fillet consumption, the percentage of children (ages 0 through 60 months) having blood lead levels greater than 10 ug/dl is less than the 5% target associated with a potential child health hazard. Therefore, adverse health effects are not expected. However, for whole fish consumption the target criterion of 10 ug/dl would be exceeded by more than 5% of the childhood population and a public health hazard might exist.

Conclusions

Evaluation of the currently available data shows that no apparent public health hazard exists for children or adults exposed to the levels of cadmium and zinc found in Spokane River fish. This conclusion is based on cadmium and zinc contamination measured in crayfish and large-scale sucker at Plantes Ferry Park.

Evaluation of the currently available data shows that no apparent public health hazard exists for adults exposed to lead through consumption of Spokane River fish f**illets**. There is also no apparent public health hazard for children exposed to lead through consumption of moderate quantities of Spokane River fish **fillets**. Some hazard may exist for children consuming large quantities of fillets. Guidelines for children's fillet consumption are given in Table 5. A public health hazard would exist for children exposed to lead through consumption of whole fish from the Spokane River.

Depending upon the consumption rate used, a public health hazard may exist for adults, specifically pregnant women, who are exposed to lead through the consumption of **whole fish** from the Spokane River. Guidelines for whole fish consumption for pregnant women are given in Table 9. Due to the uncertainty in fish consumption rates, the actual risk to adults, both male and female, who are exposed to lead through the ingestion of whole fish must be considered indeterminate at this time.

Since no data are available, the health risk due to the consumption of the edible portion of the crayfish is indeterminate at this time.

Recommendations/Public Health Action Plan

Children (ages 0 through 72 months of age) should not eat whole fish from the Spokane River or any meals prepared using whole fish from the Spokane River. It is advised that parents limit a child's number of fillet meals from Spokane River fish. Suggested meal limits are shown in Table 5 of this health consultation.

Adults, particularly pregnant women, should limit the number of whole fish eaten from the Spokane River. Suggested meal limits are shown in Table 9 of this health consultation.[27]

The Department of Ecology has issued a news release to alert the public of this finding. A health advisory for Spokane River fish consumption has also been released by the Department of Health, Ecology and the Spokane Regional Health District (SRHD). This advisory is available to the public and is also posted on all the agency web sites. Commonly used beach areas along the Spokane River will also have this advisory posted. A large outreach effort has been initiated, with SRHD as the lead agency.

Further data should be collected to determine the levels of metal contamination in edible crayfish from the Spokane River.

Department of Ecology will begin collecting these data when funding is available. DOH will review these data in conjunction with Ecology.

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Appendix A

Environmental Contamination

Table A1. Cadmium Concentrations in 1999 Spokane River Fish Samples (mg/kg)

	Stateline	Plantes Ferry	Greene Street	Trent Ave Bridge	7 Mile Bridge
Species	Whole Fish	Whole Fish	Whole Fish	Whole Fish	Whole Fish
Rainbow Trout (Wild)	0.24	0.27	0.23		
Rainbow Trout (Hatchery)					0.30
Largescale Sucker	0.35	0.25	0.19		0.21
Crayfish		0.44		0.37	0.20

Table A2. Zinc Concentrations in 1999 Spokane River Fish Samples (mg/kg)

	Stateline	Plantes Ferry	Greene Street	Trent Ave Bridge	7 Mile Bridge
Species	Whole Fish	Whole Fish	Whole Fish	Whole Fish	Whole Fish
Rainbow Trout (Wild)	45.3	50.8	40.2		
Rainbow Trout (Hatchery)					64.0
Largescale Sucker	150	106	90.8		58.8

Table A3. Lead Concentrations in 1999 Spokane River Fish Samples (mg/kg)

Species	Stateline		Plantes Ferry		Greene Street		Trent Ave		7 Mile	
	Whole	Fillet	Whole	Fillet	Whole	Fillet	Whole	Fillet	Whole	Fillet
Rainbow Trout	0.73	0.48	1.14	0.25	0.6	0.17				0.025
(Wild)		0.071		0.2		0.13				0.038
		0.11		0.055		0.11				
		0.12		0.077		0.098				
				0.081						
Average	0.73	0.22	1.14	0.16	0.6	0.12				0.032
Rainbow Trout									1.59	0.18
(Hatchery)										0.23
										0.082
										0.21
										0.20
Average									1.59	0.18

Largescale Sucker	4.34	0.088	1.77	0.047	3.12	0.12			1.8	0.059
		0.21	2.085	0.077		0.054				0.068
		0.28		0.069		0.08				0.02
		0.03		0.16		0.059				0.09
		0.036		0.088		0.094				0.046
Average	4.34	0.13	1.93	0.09	3.12	0.08			1.8	0.06
Mountain Whitefish					0.65	0.02			0.56	0.065
						0.02				0.02
						0.02				0.037
						0.02				0.02
						0.02				0.036
Average					0.65	0.02			0.56	0.036
Crayfish			1.34				0.89		0.34	

Appendix B

Adult and Child Exposure Assumptions for Cadmium and Zinc

In the analysis conducted in this consultation, adults were assumed to be exposed to metal contamination in fish through ingestion. Exposure analysis was conducted using the formula shown below:

Exposure Dose = (CF x IR x EF x ED)/ BW x AT

Cadmium: ED= (0.44mg/kg **x** 0.3198kg/meal **x** 60 meals/yr **x** 30 yrs)/(70 kg **x** 10950 days)

ED= 0.00033 mg/kg-day

Zinc: ED= (106mg/kg **x** 0.3198kg/meal **x** 60 meals/yr **x** 30 yrs)/(70 kg **x** 10950 days)

ED= 0.08 mg/kg-day

CF = concentration of contaminant in whole fish (mg/kg). Based on the contaminant levels at Plantes Ferry Park, the values for used cadmium and zinc were 0.44 mg/kg and 106 mg/kg (an average of three duplicate samples), respectively.

IR = Ingestion Rate (kg/meal)

An ingestion rate of 0.3198 kg was used. This is based upon the assumption that 2.6 fillets are consumed per meal. Each fillet was assumed to weigh 123 grams (.123 kg).[6,7]

EF = Exposure Frequency (meals/year)

It is assumed that 60 meals were consumed per year.

ED = Exposure Duration (years)

It was assumed that residents were exposed to contaminated fish for 30 years. An exposure duration of 30 years represents the 90^{th} percentile for time spent at one residence.

BW = Body Weight (kg)

For adults a 70 kg body weight is assumed. For children (ages 6 through 18) a 40 kg body weight was used.

AT = Averaging Time (days)

For exposure to carcinogens this is assumed to be 70 years x 365 days/year. For non-carcinogens, this is the actual length of the exposure period (30 years x 365 days/year).

Exposure Dose = is determined as shown above and expressed as mg/kg-day.

Appendix C

Native American Exposure Assumptions for Cadmium and Zinc

In the analysis conducted in this consultation, Native American subsistence fishers were assumed to be exposed to metal contamination in fish through ingestion. Exposure analysis was conducted using the formula shown below:

Exposure Dose (mg/kg-day) = (CF x IR x EF x ED)/ BW x AT

Cadmium: ED= (0.44mg/kg **x** 0.0863kg/day **x** 365 days/yr **x** 30 yrs)/(70 kg **x** 10950 days)

ED= 0.0005 mg/kg-day

Zinc: ED= (106mg/kg **x** 0.0863kg/day **x** 365 days/yr **x** 30 yrs)/(70 kg **x** 10950 days)

ED= 0.13 mg/kg-day

CF= concentration of contaminant in whole fish (mg/kg). Based on the contaminant levels at Plantes Ferry Park, the values for used cadmium and zinc were 0.44 mg/kg and 106 mg/kg (an average of three duplicate samples), respectively.

IR = Ingestion Rate (kg/day)

The default ingestion value, used by the Spokane Tribe, for adult fish consumption is 0.0863 kilograms of fish per day. This value is also suggested in the EPA Draft Water Quality Criteria Methodology Revisions.[28] This default value represents the 99^{th} percentile consumption rate for the general population and is withing the range of average intakes for subsistence fishers/minority anglers.

EF = Exposure Frequency (days/year)

It was assumed that fish was consumed by subsistence fishers 365 days/year.

ED = Exposure Duration (years)

It was assumed that residents were exposed to contaminated fish for 30 years. An exposure duration of 30 years represents the 90^{th} percentile for time spent at one residence.

BW = Body Weight (kg)

For adults a 70 kg body weight is assumed. For children (ages 6 through 18) a 40 kg body weight was used.

AT = Averaging Time (days)

For exposure to carcinogens this is assumed to be 70 years x 365 days/year. For non-carcinogens, this is the actual length of the exposure period (30 years x 365 days/year).

Appendix D

Values used in the IEUBK model

Table D1. Meat Consumption Rate by Age

Age Range (months)	Meat Consumption (grams/day)
12-23	87.5
24-35	95.7
36-47	101.6
48-59	107.4

Table D2. Input Parameter Values Used for the IEUBK Model

Input Parameter	Input ParameterVal ue
ValueSoil Lead Concentration	230 ppm
House Dust Lead Concentration	161 ppm
Locally Caught Fish as Percentage of Meat Consumed	16%
Lead Concentration for Stateline Rainbow Trout Fillet	0.22 mg/g

Table D3. Percentages of Children's Fish Consumption Rates, CRITFC, 1994

Grams/day	Cumulative Percent	Grams/day	Cumulative Percent	Grams/day	Cumulative Percent
0.4	1%	8.1	33%	32.4	84%
0.8	1%	9.7	35%	48.6	89%
1.6	5%	12.2	38%	64.8	93%
2.4	5%	13	39%	72.9	95%
3.2	9%	16.2	65%	81	97%
4.1	14%	19.4	66%	97.2	98%
4.9	16%	20.3	67%	162	100%
6.5	18%	24.3	70%		

Appendix E

The Adult Lead Model

Analysis of the lead hazard associated with adult consumption of Spokane River fish was conducted using the formula shown in Equation 1 below:

Equation 1: $PbB_{adult,\ central} = PbB_{adult,0} + BKSF * (PbS * IR_s * AF_s * EF_s + PbF * IR_F * AF_F * EF_F) / AT$

$PbB_{adult,0}$ = Adult blood lead concentration in the absence of other lead exposure.

BKSF = slope factor relating the (quasi-steady state) increase in typical adult blood lead concentration to average daily lead uptake (ug/dl blood lead increase per ug/day lead uptake).

PbS = Soil lead concentration (ug/g) (appropriate average concentration for the individual).

IR_s =Intake rate of soil, including both outdoor soil and the soil-derived component of indoor dust (mg/day) (central tendency estimate).

AF_s = Absolute gastrointestinal absorption factor for ingested lead in soil and lead in dust derived from soil (dimensionless).

EF_s = Exposure frequency for contact with assessed soils and/or dust derived in part from these soils (days of exposure during the averaging period); may be taken as days per year in continuing long term exposures. In this evaluation, EFs was set at 365 days per year as the CRITFC study results were expressed in fish consumed per day on a yearly basis.

PbF = Fish lead concentration (ug/g) appropriate average concentration.

IR_F =Intake rate of fish in g/day (central tendency estimate).

AF_F =Absolute gastrointestinal absorption factor for ingested lead in fish (dimensionless).

EF_F = Exposure frequency for ingestion of fish (days of exposure during the averaging period); may be taken as days per year in continuing long term exposures.

AT = Averaging time, the total period during which exposure may occur. In this evaluation, an averaging time of 365 days was used.

Table E1. Adult Lead Exposure Model Parameter Values

Parameter	Value	Reference [27]
$PbB_{adult,0}$	1.59 µg/dl	Thayer, 2001
BKSF	0.4 (ug/dl) /(ug/day)	EPA, 1996
IR_s	0.05 g/day	EPA, 1996
AF_s	0.12 unitless	EPA, 1996
EF_s	219 days/year	EPA, 1996
AF_F	0.10	EPA, 1996

For pregnant women or women desiring to become pregnant, the criterion to which the calculated adult blood lead level (equation 1) is compared to is based on protection of the developing fetus. There should be no more than a 5% probability of the fetal blood lead concentration exceeding 10 ìg/dl. The central tendency adult blood level guaranteeing protection of the fetus may be derived based on the distribution of adult blood lead levels. The formula is given in Equation 2:

Equation 2: $PbB_{\text{adult, central goal}} = (PbB_{\text{fetal, 0.95 goal}}) / (GSD^{1.645} \times R_{\text{fetal/maternal}})$

Where:

$PbB_{\text{fetal, 0.95 goal}}$ = Goal for the 95th percentile blood lead concentration (ìg/dl) among fetuses born to women having exposures to the specified site soil concentration. This is interpreted to mean that there is a 95% likelihood that a fetus, in a woman who experiences such exposures, would have a blood lead concentration no greater than $PbB_{\text{fetal, 0.95}}$. The value for this parameter is 10 ìg/dl.

GSD = Estimated value fo the individual geometric standard deviation; The GSD among adults (i.e. women of child-bearing age) that have exposures to similar on-site lead concentrations, but that have non-uniform response (intake, biokinetics) to site lead and non-uniform off site lead exposures. The exponent 1.645, is the value of the standard normal deviate used to calculate the 95th percentile from a lognormal distribution of blood lead concentrations. GSD and starting blood lead values are provided in table E2.

R = Constant of proportionality between fetal blood lead concentraions at birth and maternal blood lead concentrations.

Table E2. Combined NHANES III Phase I and II Blood Lead Data for Women (ages 17-45) Residing in the Western US by Ethnic Group

Group	Starting Blood Lead Level	Geometric Standard Deviation
All ethnicities	2.11	1.4
Non-Hispanic white	2.08	1.3
Non-Hispanic black	2.04	1.87
Mexican American	2.31	1.59

Both the starting blood lead level and the geometric standard deviation affect the conservatism inherent in evaluating lead hazard. As the difference between the starting blood level and the GSD derived cutoff decreases (equation 2), the criterion for evaluating hazard becomes more stringent. For purposes of hazard assessment, geometric means and geometric standard deviations should be paired by racial group. The smallest difference between the GSD derived cutoff and geometric mean was obtained for Mexican American women. Consequently the GSD and GM values for Mexican American women were used for hazard assessment.

Appendix F

Determination of the Adult Consumption Rates for the EPA Adult Lead Model

Recreational/Licensed Anglers

Determining the appropriate central tendency consumption rate to use for recreational anglers is fairly subjective. Studies for individuals fishing Lake Roosevelt and the Spokane River may be used to derive some recreational fish consumption values.[4,6] The DOH and SRHD studies do give some idea of the range of recreational fish consumption, although the collection of additional data to evaluate regional fish consumption using established study designs would reduce uncertainty.[13,14,15]

The SRHD survey identified a 50th percentile number of fish consumed for licensed anglers. This value is 11.12 fish per year. Assuming that the average fillet size is 123 grams (as used in the cadmium and zinc analysis), the yearly consumption rate is 2,735 grams per year. The daily consumption rate is therefore 7.5 grams per day for the licensed angler.

The Lake Roosevelt study evaluated the percentage of individuals consuming specific numbers of fish meals per year. The lowest two consumption rate categories ('less than 12 meals per year' and '12-24 meals per year') included 54% of all respondents. It would be plausible then to use 24 meals per year as a approximate central tendency measure. However, since the lowest category, 'less than 12 meals per year', may have included non-fish consumers, the next category ('24-48 meals per year') was used as the basis for a central tendency estimate and lead hazard was evaluated using a consumption rate of 48 meals per year. Seventy-two percent of all individuals consume 48 or less fish meals per year. Assuming, as discussed for cadmium and zinc, that there are 2.6 fillets per meal and that a fillet weighs 123 grams, then the daily consumption rate for licensed recreational anglers is 42 grams per day.

Russian Community

Fish consumption by the Russian population was not nearly as well characterized as licensed angler consumption.[4] Discussions with Russian community members suggested that an average consumption rate was 4 pounds per month. This is equivalent to 59.7 grams per day.

Native Americans

Though no studies of Native Americans fishing the Spokane River are available, the Columbia River Intertribal Fish Commission (CRITFC) examined Native American fish consumption rates for tribes fishing the Columbia River Basin.[13] The CRITFC study was selected as the most applicable study for developing a Spokane River fish consumption rate for adults. The median consumption rate, derived by linear interpolation, is 39.2 grams per day. CRITFC consumption rates and percentiles are shown below in Table 1 of this Appendix.

Table F1. Adult Fish Consumption Rates [13]

Grams/day	Cumulative Percent	Grams/day	Cumulative Percent	Grams/day	Cumulative Percent
1	1.80%	24.3	22.40%	162	94.20%
1.6	1.90%	29.2	22.60%	170	94.70%
3.2	3.40%	32.4	49.00%	194	97.30%
4.1	3.90%	38.9	49.30%	243	97.40%
4.9	4.00%	40.5	53.20%	259	97.60%
6.5	6.00%	48.6	65.20%	292	97.80%
7.3	6.20%	64.8	79.20%	324	98.60%
8.1	7.00%	72.9	79.90%	340	99.10%
9.8	7.80%	77	80.10%	389	99.40%
12.2	8.30%	81	82.20%	486	100.00%
13	9.80%	97.2	88.70%	648	100.20%
16.2	16.80%	130	91.80%	778	100.40%
19.4	18.10%	146	93.40%	972	100.60%
20.2	18.30%				

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